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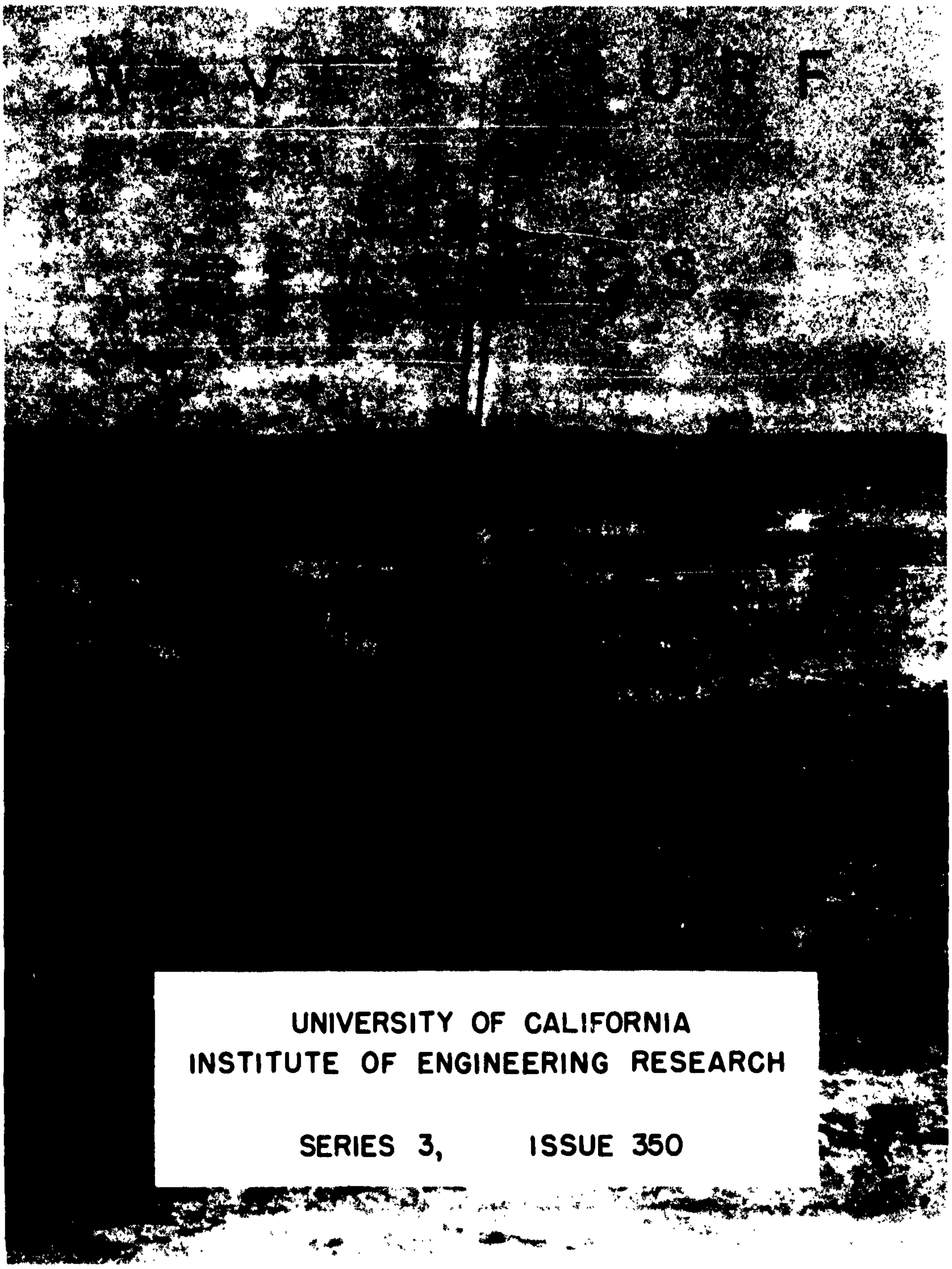

UNIVERSITY OF CALIFORNIA
INSTITUTE OF ENGINEERING RESEARCH

SERIES 3, ISSUE 350

Report No. 350

(Part 1)

CONTENTS

Report No. 350

Part 1

Introduction

Since 1944 the Department of Engineering of the University of California has conducted investigations on surface-wave phenomena for various state and federal agencies and for private industry. The first series of investigations was conducted under the sponsorship of the U. S. Navy. A list of reports completed in these studies has been presented in Report No. 300, "Final Report - A List of Reports and Publications Completed on Contract NObs 2490". Because more lately the sponsorship of the studies on wave action, beach erosion, etc. has been more widely distributed, it appears desirable to present a list of reports that have been prepared since the publication of Report No. 300. For convenience this report has been assembled in two parts. Request for the loan of any reports listed must be directed to the sponsoring agency. Whenever reports are indicated as being published, it is most desirable to review these papers, as corrections and later revisions are incorporated in the published form.

Requests for copies of Part 2 of this report must be directed to the Geophysics Branch, Office of Naval Research, Washington, D.C.

A. TECHNICAL REPORTS

I. GENERAL WAVE INVESTIGATIONS

(Series 3)
Sponsored by
the Bureau of Ships[(a)]
and the Office of Naval Research[(b)]
on Contracts NObsr 43246 and N7onr 29528.*

Issue No.

301 - Experimental Study of Surface Waves in Shoaling Water, by R.L. Wiegel, May 1949, 10 p., 12 plates.

A series of experiments were performed to compare actual wave dimensions with those given by theory for waves moving over a sloping beach. The primary consideration was the change of the water surface elevation at a point with time. It was found that this "profile" corresponded with Rayleigh's extension of the theory of waves to shoal water conditions, except in the case of rapidly shoaling water (slopes steeper than 1:10) and near the breaker zone.

302 - Effect of Surface Tension on Wave Velocity in Shallow Water, by A. J. Chinn, June 1949, 9 p., 7 plates.

When studying wave characteristics by means of a small scale model, the effect of capillary wave phenomena may greatly affect the experimental results because any surface disturbance must be subjected to both gravitational and capillary influences. Although Lamb and Milne-Thomson have treated this problem hydrodynamically, there appears to be no experimental verification existing to date.

303 - Summary Report on Shore Wave Recorder Mark III, by A.J. Chinn, 25 p., 28 plates.

Several instruments were developed by the Wave Project, University of California, Berkeley, for the measurement of ocean waves. This report summarizes the operational principle, the various stages of development, and the characteristics of one of these instruments. A comparison of the recorded wave characteristics with the forecast values also is summarized.

304[(c)] Model Study of Wave Action on Underwater Barriers, by J.R. Morison, July 1949, 26 p., 17 plates.

A model study of an underwater barrier's effect on the surf zone of a beach was undertaken. It was found that the most effective position of the barrier was directly in the breaker zone; that the most effective heights were with the barrier top within a wave height of the surface; and, that the waves most greatly affected were of relatively short period.

305[(d)] Preliminary Report on Model Studies of Sand Transport Along an Infinitely Long, Straight Beach, by Thorndike Saville, Jr., July 1949, 11 p., 12 plates.

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*Work in progress.

(a) For Reports 301-309, inclusive, direct inquiries to Code 847, Bureau of Ships, Wash. D.C.

(b) For Reports 310-349, inclusive, direct inquiries to the Geophysics Branch, Office of Naval Research, Wash. D.C.

(c) See Publication No. 36

(d) " " 65

Waves were generated in a wave tank and allowed to move onto a model beach. The incident waves made an angle with the beach, with the result that a littoral movement of sand was established. The relationship between the steady state rate of transport and the wave characteristics was investigated.

306[a] Relationships Between Wind and Waves, Abbotts Lagoon, California, by J. W. Johnson, June 1949, 6 p., 8 plates.

A series of observations on wind generated waves were made in Abbotts Lagoon, California, to better define the relationships between wind and wave characteristics on relatively small bodies of water of limited fetch. The experimental methods are described and a relationship between wave height and period as a function of fetch and wind speed is presented. Other information that is presented includes a relationship between wave steepness and wave age, wind gradients, and a typical frequency distribution of wave heights.

307 Analysis of Wave Records, by Frank E. Snodgrass and Donald E. Stiling, January, 1951, 13 p., 1 plate.

This report presents the step by step procedure used at the University of California in analyzing the records from underwater wave recorders. A discussion of errors also is presented.

308[b] The force exerted by surface waves on piles, by J. R. Morison, M.P. O'Brien, J.W. Johnson, and S.A. Schaaf, August 22, 1949, 9 p., 9 plates.

A theoretical relationship is presented which shows that the force exerted by waves on a pile is a function of two components - form drag and inertia forces. Coefficients of drag and mass obtained from model studies are presented.

309 Final Report on Wave Investigations Completed on Contract NOtsr 43246, by J. W. Johnson, August 15, 1949, 3 pages.

This report summarizes the work of the subject contract by giving an abstract of reports 301 to 309, inclusive.

310[c] The Forces Exerted by Waves on Objects, by M.P. O'Brien and J. R. Morison, August 31, 1950, 8 p., 11 plates.

A theory is developed and experimental verification is presented for the force exerted by surface waves on a submerged spherical object. The object was small compared to the wave length, and its position was near the bottom. The components of force consist of form drag and inertia forces.

(a) See Publication No. 32
(b) " " 44
(c) " " 53

Issue No.

311[a] The Thermopile Wave Meter, by J.D. Isaacs and R.L. Wiegel, March 1950, 6 p., 4 plates.

The thermopile of Mark V wave meter is designed to be a low cost, simple yet durable instrument which can be considered expendable upon its installation in the ocean. Its construction is simple. A synthetic rubber bellows is mounted on a plastic base which is in turn mounted on a brass cable connection. A thermopile is mounted inside the bellows with one group of junctions in contact with the air chamber of the bellows, and the reference junctions, insulated from the air chamber, in thermal contact with the surrounding sea water. Thus when a wave passes over the unit, the crest and trough produce a compression and expansion of the bellows with the corresponding temperature change in the gas due to the polytropic cycle. The temperature difference between the air chamber and the sea water causes an emf from the thermopile, which is transmitted to shore by means of a two-conductor submarine cable, and recorded on a commercial null recorder.

312[b] A Note on the Tangential Transfer of Energy Between Wind and Waves, by S. A. Schaaf and F. M. Sauer, April 19, 1950, 5 p.

A mathematical treatment of the transfer of energy between wind and waves by tangential friction forces is given, consistent to the second degree of approximation. The results, when compared with the basic theory previously developed, show that the inclusion of second order terms results in a more consistent theory.

313[c] The Effect of Wave Steepness on Wave Velocity, by J. R. Morison, June 27, 1950, 4 p., 7 plates.

Theoretical equations are presented for the effect of wave steepness on wave velocity. Experimental data are presented to show that for practical purposes this effect can be neglected.

314[d] A Correlating Modulus for Fluid Resistance in Accelerated Motion, by H. W. Iversen and R. Balent, June 26, 1950, 12 p., 5 plates.

The present investigation includes a development from model law considerations that results in a resistance equation of the form $F = C\frac{1}{2}\rho V^2 S$. This is identical with the normal resistance equation for steady state except for the coefficient C which, in addition to being a function of Reynolds' modulus, Froude's modulus, and the geometry, is also a function of a modulus, $A\,L/V^2$, where A is the acceleration, L is a characteristic length, and V is the velocity.

Experiments with circular disks moving perpendicular to the plane of the disk under the action of approximate constant driving forces show this resistance coefficient to be correlated by the modulus $A\,L/V^2$.

(a) See publication No. 21
(b) " " 66
(c) " " 45
(d) " " 23

315[a] An Experimental Investigation of Transonic and Accelerated Supersonic Flow by the Hydraulic Analogy, by E.V. Laitone, June 3, 1950, 9 p., 10 plates.

The fundamentals and the experimental technique for the analogy between the propagation of gravity waves on the free surface of any shallow body of liquid and the two dimensional flow of a compressible gas are briefly reviewed. The experimental investigation is then devoted to the transonic problem of the detached shock waves in front of a simple wedge moving at varying supersonic speeds. The first part of the report is mainly concerned with the experimental location of the detached shock wave in steady flow as a function of the free stream Mach number, and a correlation with existing theories. The second part of the report provides an experimental study of the effect of acceleration on the shape and location of these detached shock waves and also for some attached shock waves.

316 Idealized Model Studies of the Motion of Surface Waves, by K. Kaplan, August 1950, 23 p., 17 plates.

This report presents a brief, mostly pictorial, summary of wave action studies made under various idealized conditions in a ripple tank.

317 Idealized Reconstructions of Ocean Surface Waves as Inferred from Measurements on Twenty-five Subsurface Pressure Records, by R. R. Putz, Sept. 12, 1950, 8 p., 25 plates.

Data relating to ocean wave heights and periods from twenty-five underwater pressure records from various locations is presented in the form of "reconstructed surface-wave records". In addition there are informal comments on the following topics: Characteristics of irregular wave systems which are of practical interest and which may be subject to statistical description and prediction; action of underwater pressure instruments in recording surface wave patterns; problem of inverting action of recorder to obtain original surface trace; idealized surface pattern formed from measurements made on pressure records; ambiguities in defining and identifying separate waves, heights, and periods, and possible approaches to their resolution; possibility of persistence of features of wave system during its propagation; difficulties encountered in determining proper orientation of record charts; details of method employed in measuring the chosen heights and periods, and sources of error in these measurements; criteria employed in the selection of the records.

318[b] Wave-Height Variability; Prediction of Distribution Function, by R. R. Putz, December 1950, p. 18, 16 plates.

Results are presented from the analysis of the surface-wave data obtained from twenty-five underwater pressure recorders at various locations off the shores of the Pacific Ocean.

(a) See publication No. 41
(b) See publication No. 63

The nature and selection of the data and measured variables are described. For each of the observed sequences of waves, computed parameters characterizing the distribution of unordered heights are given as measures of distribution magnitude and variability. The distribution, from record to record, of these parameters, taken both individually and jointly, is presented. A relatively high degree of correlation constituting a nearly linear relationship is exhibited between the magnitude and the variability of the wave heights in the twenty-five records. The joint distribution, from record to record, of mean and "significant" wave heights is shown, the relatively high correlation exhibited being appropriate for prediction of one quantity from the other.

319 Mark VI Shore Wave Recorder, by F.E. Snodgrass and M.A. Hall, Sept. 1952, 3 p., 8 figures.

The Mark VI Shore Wave Recorder was designed to fulfill the need for an instrument with a high frequency response to record subsurface pressure fluctuations in the surf zone. High frequency response was obtained by using a Brush Universal Strain Analyzer (with a uniform frequency response to 100 cycles per second) and an underwater pressure head with a correspondingly high natural frequency. The Mark VI Shore Wave Recorder is composed of (i) a pressure head, (ii) a four conductor waterproof cable and (iii) a Brush strain gage amplifier and pen recorder.

320 Operation Manual for Mark IX Shore Wave Recording System, by F. E. Snodgrass and Donald E. Stiling, March 1951, 16 p., 8 plates.

Utilizing the underwater type of Wave Height and Period recorder, the surface waves are measured by recording the subsurface pressure fluctuations, caused by the wave action, and translating these fluctuations to the surface by means of theoretical relationships.

The Mark IX Shore Wave recorder system is composed of a potentiometer type pressure head (the underwater unit), an underwater electric cable, a power supply and bridge unit, and a graphic recorder.

The system was designed so as to include the following attributes: low initial cost; light weight; interchangeability of component parts; long continuous service; calibration to be essentially independent of temperature variations, and variations in tide; able to be operated in a depth as great as 100 feet; rugged construction, capable of withstanding a reasonable amount of shock; simple operation.

321[a] An Experimental Investigation of Wind-generated Waves, by J.W. Johnson and E.K. Rice, March 1951, 7 p., 10 plates.

Waves were generated by forcing wind through a covered laboratory flume. For steady state conditions measurements by means of an oscillograph were made of the wave characteristics at various

(a) See Publication No. 40

points in the flume. The significant heights and periods were determined and related to the fetch and wind speed. The height and period of the individual waves for various fetch lengths were compared by means of joint frequency diagrams. The orbital motions of particles throughout the water depth were determined from motion pictures. Particle velocities below the crest are compared with theoretical relationships. Some information on wind set-up and shear-stress coefficients are presented.

322[(a)] The Damping Action of Submerged Breakwaters, by J.W. Johnson, R. A. Fuchs, and J. R. Morison, April 1951, 10 p., 13 plates.

The results of an experimental investigation on the damping action of submerged rectangular breakwaters is presented. The experimental data also are compared with published theories. A new theory is presented which compares more favorably with the experiments than the previous theories. Also given is a summary of all available published theoretical and experimental information on the damping action of trapezoidal and triangular breakwaters, reefs of various configurations, and plane barriers of various orientations.

323[(b)] A Study of Transonic Gas Dynamics by the Hydraulic Analogy, by E. V. Laitone, June 1951, 10 p., 9 plates.

The theory of the analogy between the gravity waves propagated on the free surface of a shallow body of liquid, and the two dimensional flow of a compressible gas is investigated. It is shown that the analogy may be used for quantitative purposes only for restricted specific problems, and for valid results the water depth should be 1/4-inch and the model should be fairly large.

The analogy is then applied experimentally to several transonic gas dynamic problems in order to illustrate the above restrictions. The detached bow shock waves ahead of simple wedge shapes and cylinders are photographed and the results compared with theory.

It is pointed out that the most important contribution available from the analogy is the experimental study of the effect of acceleration on non-steady problems in gas dynamics. In this case the experimental investigation shows the effect of acceleration on the bow shock waves formed in the transonic regime.

324[(c)] Local Storms of the Pacific Coast and Their Effects on Wave and Beach Conditions, by D.K. Todd and R.L. Wiegel, June 1951, 15 p., 8 plates.

Because of the erosive action on beaches of high, short-period waves generated by local storms in near-coastal areas, the

(a) See Publication No. 36
(b) See " 41
(c) See " 69

meteorological situations causing these storms are investigated. The situations for the Pacific coast of the United States are classified, based on a study of three years of daily weather maps. The monthly and latitudinal distributions of local storms are tabulated. Forecasting problems and limitations of local storm waves are discussed. Data from two local storms at Oceanside, California are presented to illustrate the wind and wave conditions, forecasting problems, and beach effects.

325[(a)] Wave-Period Variability; Prediction of Distribution Function, by R. R. Putz, June 1951, 11 p., 9 plates.

Results are presented from the analysis of the surface wave systems obtained from twenty-five underwater pressure recorders at various locations off the shores of the Pacific Ocean. For each of the observed sequences of waves, computed parameters characterizing the distribution of unordered periods are given as measures of distribution magnitude, variability, and asymmetry. Distributions, from record to record, of these parameters taken both individually and jointly, are presented. A moderate degree of association is exhibited between the magnitude and the variability of the wave-period distributions for the twenty-five records. The wave-period distributions are characterized by three parameters, making use of the family of so-called Gamma distributions. The skewness parameter, which averaged nearly zero in these distributions, was found to exhibit a moderate degree of association with the distribution mean. Graphs are presented, comparing observed and theoretical cumulative distribution functions, the latter being provided by a fitted Gamma-type curve.

326[(b)] On the Theory of Short-Crested Oscillatory Waves, by R.A. Fuchs, June 1951, 10 p., 7 plates.

The term short-crested was introduced in order to characterize such wave systems in which the two associated wave lengths were of the same order of magnitude. Waves whose crest wave lengths were much larger than the wave length in the direction of propagation were called long-crested waves. Jeffreys made use of the shallow water theory in discussing the transformation of a mixture of short and long-crested waves moving shoreward. The dependence of the motion on the wave height was investigated by determining the second order terms in the equation for the wave profile for shallow water of constant depth. This method was open to objection, however, since it yields waves of non-permanent form in the shallow water theory. The theory of such waves is placed on a more satisfactory foundation by extending Stokes' (1847) theory for irrotational cylindrical waves in water of finite depth to the general case of short-crested waves. All systems of periodic rectilinear waves are readily obtained by choosing the involved parameters appropriately; in particular cylindrical waves are included by choosing the wave number in the crest direction equal to zero or equivalently by choosing the wave length in this direction to be infinite. The calculations

(a) See Publication No. 63
(b) " " 16

are carried out to the second order of approximation, neglecting terms of the order of the cube of the wave height. The transformation of short-crested waves on a sloping beach is approximately determined by assuming that the power transmitted with the waves is conserved. A typical interference pattern of a simple short-crested wave group is obtained by superimposing two short-crested waves having nearly the same periods and wave-lengths and the same amplitude. Finally we discuss the case, of perhaps most practical interest, namely the motion of waves generated by an initially localized displacement.

327 The Generation and Decay of Wind Waves in a Sixty-foot Channel, by C.L. Bretschneider and E.K. Rice, July 1951, 5 p., 11 plates.

An experiment on the generation and decay of wind waves was performed in a sixty-foot wave channel at the University of California, Berkeley. Photographs, as well as measurements, reveal the similarity between the laboratory waves and ocean waves. From the wave measurements, data were tabulated and the results were compared with the original Sverdrup and Munk theory of wave generation and wave decay. The data of wave generation substantiate previous wave channel measurements. The data of wave decay does not substantiate Sverdrup and Munk's theory of the decay of waves.

328[a] Joint Variation of Wave Height and Wave Period for Ocean Swell, by R.R. Putz, October 1951, 8 p., 8 plates.

This report presents graphically the joint two-dimensional frequency distribution of wave height and wave period for individual waves making up twenty-five twenty-minute observed wave systems. For the type of data considered - ocean swell derived from subsurface pressure record data - it is concluded that little relation between height and period of individual waves exists. The relation between a "significant wave period" given by a particular definition and the overall mean wave period is found to be a rather close one, with a tendency for the former to exceed the latter slightly. The joint frequency distribution of wave-system parameters describing wave-height distribution and wave-period distribution are found to give no evidence of relations between these quantities for the data considered.

329[b] Damping of Water Waves by Vertical Circular Cylinders, by R.D. Costello, August 1951, 7 p., 6 plates.

When considering the wave height transmission capacity of a dense pile structure, the spacing between piles transverse to the wave front is of considerable importance and it is upon this characteristic length that studies should be based, thereby permitting a comparison with the effects of longitudinal spacing of piles. The results of this series of model experiments

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(a) See Publication No. 63
(b) " " " 10

indicate that the relative depth parameter of d/L may be neglected in the comparison of various transmission capacities. The overall results of the experiments show rather conclusively that a moderately dense piled structure is highly selective in its capacity to reduce wave action. Its ultimate transmission capacity for a given test section depends upon the magnitude of the incident wave steepness.

330[a] Heights and Periods of Pairs of Successive Waves for Ocean Swell, by R.R. Putz, October 1951, 7 p., 13 plates.

Results are presented from the analysis of the surface wave systems inferred from twenty-five underwater pressure records made at various locations off the shores of the Pacific Ocean. For each of the observed wave systems, graphs are presented showing the joint distribution of the heights and also between the periods of all pairs of consecutive waves. Computed parameters (correlation coefficients) are given as measures of the degree of linear association between the heights as well as of the periods of two consecutive waves. The joint frequency distributions, over all the observed wave systems, for these correlation coefficients and other wave system parameters are presented graphically.

331[b] Discussion of Results from Studies of Wave Transformation in Shoaling Water, Including Breaking, by H.W. Iversen, March 1952, 16 p., 5 plates.

In view of the limited knowledge of a complete description of breaker action, laboratory studies were made to obtain evidence of the geometry and kinematics of breakers for a range of incident wave characteristics, and for various beach slopes. During the course of the breaker studies some questions were raised regarding the transformation of wave heights in shoaling water prior to the breaker point. Fortunately, some laboratory studies had previously been made. It is the purpose of this report to unify the data obtained from these studies. An attempt has been made to describe breakers for the limited range of initial wave characteristics and the limited range of beach slopes which could be placed in the available laboratory wave channel. Due to the varied asymmetrical shapes of breakers such a description is limited. The summary results as presented point out enough of the salient features of breaker action to permit comparison of effects of the prime variables of initial wave characteristic and of beach slope.

332[c] Model Study of Amphibious Breakwaters, by D.A. Patrick, October, 1951, 20 p., 19 plates.

Curves have been developed from laboratory experiments which indicate the effectiveness of various orientations of a type of model floating breakwater. Comparisons are shown between the model orientations and some arrangements of rectangular blocks.

(a) See Publication No. 63
(b) " " 22
(c) " " 56

The major variables have been identified. The results presented herein are based upon a two-dimensional study in a 1 foot x 3 feet x 60 feet wave channel. The prototype conditions which have been represented in these model tests are: (i) waves ranging as high as 7 feet with a 12 second period, 16 feet with a $6\frac{1}{2}$ second period, and 25 feet with a 10 second period; (ii) water depths ranging from 30 to 60 feet; (iii) a Navy Lighter pontoon structure 175 feet long and of unit width. Breakwater efficiencies up to 90% were noted in a few cases for some of the shorter period waves. Qualitative observations indicated mooring stresses ranged from very small to zero in a large number of instances. These results are encouraging, but additional experiments and analyses are needed.

333 Waves, Tides and Beaches: Glossary of Terms and List of Standard Symbols, by R.L. Wiegel, September 1, 1951, 43 p., 10 plates.

For many years, workers in the field of physical oceanography have needed standardized definitions of the terms they used. The most complete glossary to date is the "Coast and Beach Glossary for Amphibious Intelligence Use", prepared in 1949 by the U.S. Naval Interpretation Center. This glossary redefined many terms, coined others, and used photographs and sketches to illustrate some difficult concepts. In preparing the present glossary, the University of California's Waves Investigation Group used the 1949 Glossary, but enlarged its scope, and tried to further clarify many of the definitions. They studied all relevant literature - including government reports, basic tests, and scientific journals - and then worked out the best all round definition for each term included. As these definitions are combinations of so many sources, no specific acknowledgments are made. A list of standard symbols has also been prepared for use by investigators in the fields of physical oceanography.

334 Wave Forces on Piles: A Diffraction Theory, by R.C. MacCamy and R.A. Fuchs, Feb. 1, 1952, 14 p., 7 plates.

This report contains two main results. In the first section an exact mathematical solution is presented for the linearized problem of water waves of small steepness incident on a circular cylinder. The fluid is assumed to be frictionless and the motion irrotational. This section includes, in addition to the formal mathematical treatment, some simple deductions based on the assumption of very small ratio of cylinder diameter to incident wave-length. The principal results of the theory are summarized, for convenience in calculation, in the second section. Also presented are some suggestions as to possible extensions of the theory to take care of more extreme wave conditions and other obstacle shapes. The second result is an attempt to apply the theory to the computation of actual wave forces on cylindrical piles. The basis of comparison is a series of tests performed in the wave channel. The agreement is found to be quite good in the region in which the assumptions of the theory are fairly closely realized.

335 Theory of Surface Waves Produced by Underwater Explosions, by R.A. Fuchs, May 3, 1952, 9 p.

The method of sources and sinks is employed to determine the wave motion produced by an oscillating gas bubble generated by an underwater explosion. The most general model considered is that of a bubble having radial symmetry about a vertical line. For spherical bubbles the results obtained agree with those of Kirkwood and Seeger.

For bubbles having a small period of oscillation the method of stationary phase is employed to obtain approximate results. Two particular models are discussed, the first so-called bubble collapse predicts the first disturbance to be a trough while the model of bubble expansion predicts a crest. Comparison with experimental data presented elsewhere indicated that the bubble collapse and bubble expansion models agreed quite well with results for deep and near surface explosions, respectively.

336 Analysis of Subsurface Pressure Records in Constant Depths and on Sloping Beaches, by J.R. Morison, 26 p., 34 plates.

A method based on the linear wave theory is presented for the reconstruction of the surface wave time history by harmonic analysis from the subsurface pressure records in water of constant depth. Several methods of analyzing pressure records and computing the surface conditions are compared to experimental results of model and field tests. The harmonic analysis method gave the best agreement with the measured surface fluctuation both in form and amplitude. Measurements of the subsurface pressure fluctuation on a sloping beach in relatively shallow water are presented. All wave theories investigated showed poor agreement with the experimental results.

337 Prediction of Linear Effects from Instrument Records of Wave Motion, by R.A. Fuchs, June 1952, 8 p., 4 plates.

Quantitative data on wave motion is commonly recorded automatically by fixed instruments such as for example: - inverted echo sounders, wire resistance elements and underwater pressure recorders. These instruments record certain hydrodynamic effects intimately related to other effects taking place under these conditions such as the force exerted on a seawall or pile, the oscillations of a ship, wave transformation on a neighboring beach, etc. The linear theory of irrotational motion furnishes a model by means of which the prediction of these other effects from instrument records can be carried out. The method considered here was first described for bottom pressure fluctuations and surface amplitudes by Kreisel. Using a Fourier integral representation of the wave motion the subsurface pressure fluctuation is represented as a convolution type integral of the surface amplitude and a standard kernel function which depends on the depth of water. This kernel has been computed by the Admiralty Computing Service with the object of testing the validity of the linear theory.

338[a] Sand Transport by Littoral Currents by J.W. Johnson, June 1952, 14 p., 8 plates.

The results of a series of model studies on sand transport by wave induced littoral currents are presented to show rate of transport as a function of wave characteristic. Also summarized are the results of field observations of sand transport as obtained from the harbor accretion at Santa Barbara, California.

339 Translation of "Theory of Waves" by Franz Gerstner, 19 pages, 1 plate, September 1952.

This theoretical treatment by Gerstner was originally published in Abhandlungen der Koenigl. boehmischen Gesellschaft der Wissenschaften zu Prag, 1802. This report, however, was translated from an article in German which appeared in Annalen der Physik, vol. 32, 1809. This translation has been issued because this classic paper is not available in an English translation in this country.

340 Telemetering of the Mark IX Shore Wave Recorder Output, by F. E. Snodgrass and E. W. Skiff, 10 pages, 1 plate, Sept. 1952.

This report describes a telemetering system which can transmit records from a wave recorder over the telephone lines of the Bell System, thereby permitting a central office to obtain wave data from any of various shore stations.

341 A Means for Remote Control of the Wave Recorder Telemetering Transmitter, by F. E. Snodgrass and E. W. Skiff, 6 pages, 1 plate, Sept., 1952.

This report describes equipment that permits an operator to terminate a telephone call at any time from 1 to 30 minutes after a call is started. This system sends a "stop" signal from the receiving end to the transmitting end - while the main transmitter is sending data from the transmitting end to the receiving end.

342 Ocean Wave Measurements, by F. E. Snodgrass, 43 pages, 23 plates, August 1952.

This paper reviews the instruments that have been developed for the measurement of ordinary gravity waves (periods of 1 to 30 seconds) and to suggest possible solutions to measurement problems that exist today. Only the measurement of ocean waves that generally are of concern to the engineer are discussed. Many other measurements of the sea surface are important, but are considered beyond the scope of this paper.

343 An Electronic Instrument for the Statistical Analysis of Ocean Waves, by W. W. Lund, 27 pages, 24 plates, Sept. 1952.

This report describes an electronic instrument that is the result of an attempt to develop an accurate and stable analogue computer to aid in the analysis of ocean wave data. It is a self-contained instrument in that it requires no auxiliary calibrating

(a) See Publication No. 39

equipment. Information is fed into the instrument in the form of an electric voltage. The output data are presented by direct-reading counter dials. Although the instrument has some small imperfections, its operation so far has proven to be quite satisfactory.

344 The Mechanics of Deep Water, Shallow Water and Breaking Waves, by J. R. Morison and R. C. Crooke, 9 pages, 5 plates, February 1953.

Experimental data are presented for deep water, shallow water, and breaking waves with respect to the wave surface time history, the horizontal and vertical particle velocities and the particle orbits. The measurements are compared where applicable to Stokes wave theory. The results are that the Stokes wave theory, and other wave theories, show good agreement with the measurements for deep water conditions and even to d/L values of approximately 0.2. The theories do not apply for shallow water conditions where d/L values are appreciably less than 0.2 and the waves have an appreciable steepness.

345 The Force Distribution Exerted by Surface Waves on Piles, by J.R. Morison, 7 pages, 1 plate, March 1953.

Experimental data for the force distributions in three model cylindrical piles for three wave conditions are presented. The results are compared with a previously published theory.

346 Ripple Tank Studies of the Motion of Surface Gravity Water Waves, by Osvald Sibul, 11 pages, 9 plates, February 1953.

This report presents the results of a ripple tank study of various idealized conditions involving the refraction, diffraction, reflection, and decay of surface waves.

347 Forms of Equilibrium of Coasts With a Littoral Drift, by Per Bruun, 7 pages, 32 plates, February 1953.

It is shown that the form of some coastal features where a littoral drift exists can be explained by the solution of a very simple differential equation for the relationship between the intensity of lit toral drift and the deep water characteristics of the waves. Other beac forms under less idealized conditions may be explained from a similar relation. Different types of marine-forelands can be explained as a result of refraction and diffraction in connection with a lowering of the steepness ratio of the waves.

348 A Model Study of Wave Run-up on Sloping Structures, by K. N. Granthem, 15 pages, 19 plates, February 1953.

Curves have been developed from laboratory experiments which indicate (1) the effect of different side slope angles of a sloping structure on wave run-up, (2) the effect of the parameter wave steepness (H/L) on wave run-up on sloping structures,

(3) the effect of the parameter relative depth (d/L) on wave run-up on sloping structures, and (4) the effect of structure porosity on wave run-up. Maximum wave run-up occurs, for the range of angles examined, at approximately 30 degrees. As the wave steepness parameter (H/L) increases, the wave run-up increases and, as the relative depth parameter (d/L) decreases the wave run-up increases.

349 Wave Data for San Francisco Bay and Vicinity, by J. W. Johnson, 3 pages, 5 plates, February 1953.

This report summarizes the known data on wave heights and periods for San Francisco Bay and vicinity. These data are presented in the form of graphs to show the frequency of occurrence from various directions. Where possible, "wave roses" are presented for the various months of the year.

350 Summary of Research on Waves, Surf, and Beaches, by J. W. Johnson and R. L. Wiegel, Part I, 23 pages, and Part II, 16 pages, March, 1953.

This report gives a list of reports, with abstracts, that have been completed on waves and related subjects by the Institute of Engineering Research, University of California.

II. BEACH STUDIES

(Series 14)

Sponsored by

The Beach Erosion Board, Corps of Engineers
on Contracts W49-055-Eng-2 and DA-49-055-Eng-8*

Issue No.

1 (Not for public release)

2[(a)] The Relationship Between Sand Size and Beach Face Slope, by W. N. Bascom, 7 p., 7 plates.

A series of diagrams is presented which illustrates the variability of sand size and beach-face slope and the relationship between the two as observed on Pacific Coast beaches of the United States. As a means of standardizing sampling procedures, a "reference point" (the part of the beach face subject to wave action at mid-tide level) was adopted, which permitted satisfactory comparisons of beach characteristics. Distribution of sand sizes along and across beaches is described, and slope changes with beach growth and erosion are illustrated. It is shown that beach-face slope is principally controlled by two factors: (1) the size of the sand and (2) the intensity of wave action.

3 Initial Surveys and Instrumentation, Sand Transport Study, Santa Barbara, California, by W. N. Bascom, July 20, 1950, 4 p., 58 plates.

This report outlines the surveying and instrumentation program in connection with the sand transport study at Santa Barbara, California. The first set of beach profiles are given along with maps for referencing the ranges for future surveys.

4[(b)] Wave Records on the Pacific Coast of the United States, by J. W. Johnson, Sept. 7, 1950, 2 p., 10 tables, 1 plate.

The report summarizes the location and periods for which known wave data from wave recorders and the hindcasting procedure are available for the Pacific Coast of the United States. Daily records are given for Pt. Sur, Calif., for the period April 15-May 24, 1950 and for Pt. Pinos, Calif., for the period March 29-June 16, 1950.

5 Sand Studies in Two Dimensional Wave Motion, by E. A. Shay and J. W. Johnson, November 1950, 16 p., 36 plates.

Although the experiments described herein were intended primarily to provide certain qualitative information for conducting an investigation on the littoral movement of beach material, some of the results are of general value and a summary of these data appear desirable. The purpose of the tests was to determine the

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*Work in progress
(a) See publication No. 4
(b) See publication No. 67

behavior of various specially prepared relatively fine sands when subjected to wave action. These tests indicated that a stable beach could be established for a particular sand only if the range of grain sizes in the mixture was relatively small, as usually is the case for most of the natural beach sands. Sand mixtures with a relatively large range of grain sizes appeared to give a large range in beach profile for the same wave conditions. Any attempt to predict a beach profile for a given wave condition therefore appears impossible with such mixtures.

Within the limits of the experiments on those sands which were considered suitable for model tests, there appeared to be a definite relationship between the foreshore slope and berm height with the wave period.

In addition to the effect of sand mixture on the development of equilibrium profiles, tests also were made to determine the effect of tide and also the period change on the character of beach profiles. These tests indicated that, with the material used in the experiments but transposed to prototype conditions, the profile changes which take place as a result of a period change would require such a length of time that they would probably be confused with those resulting from purely the tidal action.

6 Influence of Groins on Beach Stabilization, by E. A. Shay and J. W. Johnson, January 19, 1951, 20 p., 29 plates.

In this study a sand beach was placed at one end of a model basin. Waves were generated at the opposite end of the basin and moved toward the beach. These waves breaking along the shore induced a current which caused a littoral movement of the sand. The relative effect of a particular type of groin was determined by comparing the topography of a straight, unobstructed beach which had reached an equilibrium profile with the topography of a beach which had reached equilibrium after a groin or system of groins were installed.

7[(a)] Model Studies on the Movement of Sand Transported by Wave Action along a Straight Beach, by E. A. Shay and J. W. Johnson, February 8, 1951, 26 p., 8 tables, 32 plates.

This report covers the experimental work made on the movement of sand transported along a straight beach unobstructed by fixation works. Waves breaking at an angle to a beach generate a littoral current which is capable of moving sand. Observations in the laboratory have thus far brought out two relationships which show how the transport rate varies, the one relationship being between the littoral current and the amount of sand transported, and the second relationship being between the wave steepness ratio and the amount of sand transported. A method for estimating the amount of transport, knowing the littoral current, is presented for a limited set of conditions.

(a) See publication No. 39

8 Investigation of Coastal Sand Movement, Santa Barbara, California, by W. N. Bascom, January, 1951, Part I, 38 p., Part II, 78 plates.

This report is a statement of work accomplished to date on coastal sand transport in the Santa Barbara area by the University of California, Berkeley. Funds have been expended largely to obtain data, the bulk of which are herein presented.

9 Final Report on Sand Transportation by Wave Action, May 1951, 14 p.

This report presents a summary of the work completed on Contract W-49-055-Eng-2 and previously reported in Issues Nos. 1-8, inclusive, of Series 14.

10[(a)] Stationary Dredge for By-Passing Sand at Salina Cruz Harbor, Isthmus of Tehuantepec, Mexico, by Parker D. Trask, January 1952, 7 p., 10 plates.

Puertos Libros Mexicanos (Board of Mexican Free Ports) has recently installed a stationary dredge for the purpose of by-passing sand around the entrance to the harbor at Salina Cruz, Mexico. Previously, sand that accumulated in the harbor was removed by means of a floating dredge, but in view of the cost of operating this dredge the officials of Puertos Mexicanos Libros felt that it would be expedient to construct a fixed dredge (draga fija) supplied with suction pumps and pipe line to by-pass sand around the harbor before it has a chance to enter the port. Construction was completed and the dredge was ready for operation early in 1951 but difficulties have been encountered in causing sand to come to the dredge in a fashion that it can readily be pumped away by the suction pipes. At present the engineers of Puertos Libros Mexicanos are attempting to iron out these difficulties. Thus far, 15,000,000 pesos ($2,000,000) is said to have been spent on the project.

11[(b)] Source of Beach Sand at Santa Barbara, California, as indicated by Mineral Grain Studies, by Parker D. Trask, May 1952, 17 p., 6 plates.

The construction of the breakwater to improve Santa Barbara harbor has developed critical problems. Sand continually collects in the harbor behind the breakwater and at the same time is eroded from the beaches east of the harbor. Knowledge of the mechanics of sand movement in this region would help conserve both the beaches and the harbor and at the same time would yield information which would help control shore lines in other parts of the world. A systematic quantitative study of (1) the accumulation of sand in the harbor and (2) the rate of erosion of the beaches east of the harbor has been undertaken for some time by the Institute of Engineering Research.

(a) See publication No. 70
(b) " " " 72

An integral part of the problem at Santa Barbara is the source of the sand. One possible means of determining the source is mineral grain studies. Two studies of the mineral composition of the sand at Santa Barbara were made: (1) in the harbor itself in order to ascertain if the mineral content varied significantly in and near the harbor and associated beaches; and (2) along the coast west and north of the harbor for a distance of more than 250 miles, in order to investigate migration of sand along the coast.

The first study in the immediate area of Santa Barbara showed no distinctive difference in mineral content. Consequently it contributed little information of aid in understanding sand movement between the harbor and the beaches to the east. The second study of sand along the coast west of Santa Barbara, has shown very clearly that a significant proportion of the sand at Santa Barbara comes from a distance of more than 100 miles up the coast. Of special significance is the fact that this sand moves around Pt. Conception.

12[a] Santa Barbara Studies; Compilation of Basic Data, by P.D. Trask, July 1952, 2 p., 104 plates, 24 tables.

This report is a collection of beach profiles, maps, mechanical analyses, mineral counts, and other basic data collected during the study of sand transport at Santa Barbara. These data are assembled in report form in order that the Beach Erosion Board will have this information on file for future reference.

13 Effect of a Littoral Barrier on a Sandy Coast, by Ning Chien and Huon Li, August 1952, 7 p., 8 plates.

A photographic record of the effect of a littoral barrier on a sandy coast is presented. This study shows that when the normal littoral drift of sand is interrupted by the installation of a barrier, the rate of drift around the barrier will be resumed only when the impounding basin of the barrier is filled by the sediment coming from the upcoast side. After the resumption of the normal drift past the littoral barrier, the beach profile remains more or less the same as that of the equilibrium coast before the installation of the barrier, only its relative position is shifted. The rate of littoral drift and the sorting of material across the beach are also discussed briefly.

(a) See publication No. 72

III - WAVE RECORDERS

(Series 26)

Sponsored by
The Bureau of Yards and Docks, State of Illinois
Naval Research Laboratory, and U.S. Marine Corps

Issue No.

1[(a)] The Testing and Calibration of the Mark III Shore Wave Recorders, June 16, 1948, 6 p., 28 plates.

The University of California under Contract NOy 14745 with the Bureau of Yards and Docks undertook the responsibility of supervising and testing a group of Mark III shore wave recorders manufactured by the Mare Island Naval Yard. These recorders, also known as differential pressure meters, were installed in the Marianas Area for the purpose of studying the characteristics of waves and surges in Apra Harbor at Guam.

2[(a)] Progress Report on Wave Measurements at Apra Harbor, Guam, by A. J. Chinn, July 5, 1949, 7 p., 3 plates, 10 tables.

This report contains a description of the installation of wave recorders and a summary of 5 months of records.

3[(a)] Summary Report on Wave Measurements at Apra Harbor, Guam, Marianas Islands, by A. J. Chinn and E. W. Winkler, August 1950, 34 p., 26 tables, 39 plates.

This report presents a complete summary of all the data obtained during the period of observation. The objectives of this study were (a) to obtain data in regard to wave conditions inside Apra Harbor, (b) to perform field observations and compare the results therein with similar conditions obtained in a model investigation, (c) to compile a one year record of wave heights, wave periods, and wave direction, and to formulate a statistical summary of the wave characteristics for this part of the Pacific Ocean, and (d) with the Woods Hole profile recorder to obtain wave records for frequency analysis of wave characteristics and to correlate the results with the method of storm tracking.

4 Wave Recorders also have been installed at the following localities, but no reports on these installations were prepared.

a. Division of Waterways, State of Illinois.

(i) Lake Michigan, Wilson Avenue Intake Crib, Chicago, Ill.
(ii) Lake Michigan, Waukegan, Illinois

b. Naval Research Laboratory

Cocoa Beach, Florida

c. U.S. Marine Corps

Camp Pendleton, California

(a) Work completed on Bureau of Yards and Docks contract No. NOy 14745.

IV. WAVE FORCES ON STRUCTURES
(Series 35)

sponsored by

a. International Marine Platforms, Inc., San Francisco, Calif.,
b. The California Co., New Orleans, La.,
c. Bureau of Yards and Docks, Washington, D.C.
d. Signal Oil and Gas Co., Los Angeles, Calif.

Issue No.

1[a] Moment Distribution on a Stepped Caisson, by J. R. Morison, April 24, 1950, 3 p., 9 figures, 1 table.

The distribution of moment resulting from wave action on a caisson consisting of various diameter cylindrical sections was determined by model studies in a wave channel.

2[c] Moment Distribution Exerted by Waves on Piling, by J.R. Morison, October 1950, 2 p., 3 plates.

A model study was made of the moment distribution on a pile of uniform cross-section. Experimental and theoretical distributions were compared.

3[b] The Forces Exerted by Waves on Marine Structures, by J.R. Morison, October 20, 1950, 13 p., 16 plates, 10 tables.

A laboratory investigation of the forces exerted by waves on selected structural shapes was made for the purposes of presenting design information for the engineers engaged in the construction of structures that are exposed to wave action. The tests were made on model piling and cross members for deep water and shallow water wave conditions with emphasis being placed upon the latter conditions and upon steep waves.

4[c] Wave Forces on Piling (Monterey Field Test), by F. E. Snodgrass, E. K. Rice, and M. A. Hall, June 1951, 9 pages, 18 plates.

This investigation was intended to determine the magnitude of the moment exerted on a $3\frac{1}{2}$-inch diameter test-pile located in and near the breaker zone. The experiments serve to develop and perfect techniques for measuring both the wave characteristics and wave moment on piling. Due to the immediate need for information on the wave forces exerted on marine structures, the data of this experiment are presented in detail without a comprehensive analysis, in the hope that the methods of measurement and the results will prove of value in the solution of present problems and in the design of future experiments.

(a) Completed on a Service to Industry contract with International Marine Platforms, Inc., San Francisco, Calif.
(b) Completed on a Service to Industry contract with The California Company, New Orleans, La.
(c) Completed on Bureau of Yards and Docks contract No. NOy19849.

Issue No.

5[c] Forces on Piling - Final Report, by H. W. Iversen and J. R. Morison, August 1951, 20 p., 5 tables, 13 plates.

A summary of the laboratory work done to enable prediction of forces exerted by surface waves on piles is presented in Part I. Experimental results of model studies are presented. Coefficients are obtained from the model results for use in force and moment equations to compute forces and moments on piling under given wave conditions. Certain anomalies are shown which have not been completely reconciled into complete correlations.

In Part II results of the field pile study made at Monterey, California, are presented. These results are for limited ranges of wave conditions which were not included in the range of conditions of the model tests. No comparison can be made of the field results and the model results. The field tests show the feasibility of obtaining reliable data under natural prototype systems. Some instrumentation refinements are necessary to obtain results which will be sufficiently precise to segregate the defining parameters of the phenomena.

6[d] Ellwood Field Pile Studies - Preliminary Report, by F. E. Snodgrass, J. R. Morison, M.A. Hall, K. N. Granthem, and R. L. Wiegel, January 1952, 27 p., 40 plates.

The primary purposes of the study were (1) to obtain prototype data of forces exerted by waves on piles and (2) to compare these data with results from model studies and theoretical equations for predicting the wave forces on piles. These data were obtained by measuring the force necessary to restrain hinged prototype piles at the same time that wave measurements were being made. The tests on prototype piles were made at a station located at the end of the Signal Oil and Gas Company pier at Ellwood, California.

7[d] Ellwood Field Pile Studies - Application of Diffraction Theory, by R.C. MacCamy, March 1952, 6 p., 7 plates.

A series of experiments were completed at Ellwood pier to determine the forces exerted by ocean waves on cylindrical piles. An analysis has been made in an effort to compare these experiments with results obtained on models in a wave channel. Independently of these model studies a purely theoretical treatment of the problem has now been developed. Comparisons of the latter and the model studies indicated good agreement, and it was felt desirable to extend this comparison to prototypes. This report gives the results of an application of the theory to the pile studies at Ellwood.

(c) Completed on Bureau of Yards and Docks contract No. NOy 19849

(d) Completed on a Service to Industry contract with the Signal Oil and Gas Company, Los Angeles, Calif.

Issue No.

8[d] Ellwood Field Pile Studies: Experimental Determination of the Coefficient of Mass, by K. N. Granthem, March 1952, 6 pages.

This report presents the values of the coefficient of mass computed from the Ellwood field data. Comparisons of these data with theoretical and model study values also are presented.

(d) Completed on a Service to Industry contract with the Signal Oil and Gas Company, Los Angeles, Calif.

V. AMPHIBIOUS OCEANOGRAPHY
(Series 29)

Sponsored by the U.S. Marine Corps on Office of Naval Research Contract No. N7onr 29519 (Contract completed).

See Part 2, pages 1 to 10 for the 52 reports completed on this project.

VI. AMPHIBIOUS CRAFT
(Series 30)

Sponsored by the U.S. Marine Corps on Office of Naval Research Contract No. N7onr-29517 (Contract completed).

See Part 2, pages 11 to 12, for the 7 reports completed on this project.

VII. AMPHIBIOUS OCEANOGRAPHY MANUAL

Sponsored by the U.S. Marine Corps on Office of Naval Research Contract N7onr 29535 (Contract completed).

See Part 2, pages 13 to 15, for the work completed on this project.

VIII. UNDERWATER EXPLOSION RESEARCH
(Series 42)

Sponsored by the Office of Naval Research on Contract No. N7onr 29532.

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